

Transportation Connectivity Whitepaper

Contents

Transportation Connectivity	1
Introduction	2
Defining Connectivity	2
Equity Considerations	3
The Importance of Measurement.....	4
Literature Review	5
Connectivity Measures in Practice by Local Governments.....	5
Measuring the Equity of Regional Connectivity.....	11
Academic and Theoretical Examples	14
Analysis	16
Next Steps and Application.....	17
Conclusion.....	17

Introduction

From an article by Dr. Levine in 2011:

“An experienced Australian traveler once said that on business trips to Australian cities he could reckon to make four meetings in a day,” wrote John Thomson in 1977. “In Europe he could manage five; in the United States he could manage only three.” The reason behind the variations in this traveler’s itineraries was not an American propensity for long meetings, or the speed of travel in American cities. Instead, his schedules were determined by the great distances—and hence long travel times—separating his business contacts in metropolitan areas of the United States. What the traveler wanted was personal contact with the people with whom he did business. The speed with which he was able to travel was relatively unimportant to him; much more central was the amount of interaction he could accomplish in a given time.¹

This anecdote fittingly expresses the difference between mobility and accessibility, and by extension the metrics by which transportation systems are assessed. When evaluating the performance of a transportation system, traditional engineering practice has prioritized faster vehicle operating speeds.

As a result, most current transportation performance metrics have focused on safety, state of good repair and mobility, or how quickly people can get from point A to point B.

While there are some people that take a Sunday drive, most people do not travel solely for enjoyment, but in order to reach the places that they want to go. Everyday millions of Americans use the transportation system to reach jobs, schools, healthcare, and retail shopping. How far and how long it takes them to accomplish these daily tasks is the subject of this paper.

Defining Connectivity

Connectivity, or accessibility, is the degree to which the transportation system provides access to essential services and other destinations. In other words, how well the transportation network connects people to the places they need to go. A number of factors affect accessibility including mobility (physical travel), land use patterns (the geographic distribution of services and activities), and mobility substitutes such as telecommunications and delivery services.

Mobility, on the other hand, is about moving people and goods from place-to-place. Higher mobility is good for society, the economy, and cities as mobility provides a way measure physical ability to travel, but it is not access alone. Also, accessibility does not provide mobility.

No national standard or database exists to measure the performance of the transportation system based on access or connectivity for residents or employees. The measures now being used by some states, local governments, and academics use a variety of datasets and methodologies, influence decision-making in different ways, and can take years to develop. These considerations are explored further in this paper.

¹ Levine, Jonathan. “Getting There: From Mobility to Accessibility in Transportation Planning.” *Resources for the Future*. 2011. www.rff.org/Publications/WPC/Pages/Getting-There-From-Mobility-to-Accessibility-in-Transportation-Planning.aspx

Equity Considerations

But first, it is important to note that connectivity concepts are particularly important for people who don't always have mobility particularly low-income and economically disadvantaged populations. Research shows that environmental justice (EJ) communities have longer, more unreliable commutes. This is due to multiple reasons, one such being job sprawl and the suburbanization of employment.² The shift of employment from urban to suburban left many low-income and economically disadvantaged individuals separated from the workforce. Since many of these populations are usually concentrated, particularly in urban areas, these populations experienced severe reduction in job opportunities.³ Based on a study using 2011 U.S. Census Bureau data, associate professor Virginia Parks found that African Americans spend more time than any other group getting to work. On average, African American commute times are 15 more minutes than Caucasians. The author noted that in cities, African Americans continue to experience pronounced spatial disadvantage as a result of historic racial residential segregation and a jobs-housing mismatch, closely related to the spatial mismatch hypothesis.⁴ This jobs-housing mismatch results in longer commute times, resulting in more expense on private and public transportation.

Transportation and economic opportunity are deeply interconnected. Transportation is second to housing as the largest expense for American households, costing more than food, clothing, and health care. Costs by mode of transportation also vary widely. Public transit costs typically run from \$800 to \$1500 per worker, per year, while average car costs exceed \$6000 per year. These costs can impact low-income families disproportionately. While the average American household spends 18% of its income on transportation, this share is as high as 33% for low-income households.⁵ Costs are higher for families living in areas with sprawling land-use patterns and high automobile mode shares.

Low-income communities have lower car ownership rates than higher income areas. Households with annual incomes of less than \$25,000 are seven times less likely to have a car than those with higher incomes in a typical community, 20-40% of the population cannot drive due to age, poverty or physical impairment and so depend significantly on walking, cycling and public transport.⁶

While low-income populations rely more heavily on transit and non-motorized systems, low-income areas have less access to infrastructure to support these modes of non-motorized travel. For instance, 89 percent of high income neighborhoods have sidewalks while only 49 percent of low-income neighborhoods do. These disadvantaged areas also have less street lighting, fewer cross walks and much less traffic calming measures.⁷

² Raphael, Steven and Michael Stoll. "Job Sprawl and the Suburbanization of Poverty." *Brookings Institution Metropolitan Policy Program*. March, 2010.

³ Kain, John. "Housing Segregation, Negro Employment, and Metropolitan Decentralization." *Quarterly Journal of Economics*. 1968.

⁴ Parks, Virginia. *Density for All: Linking Urban Form to Social Equity*. 2014.

⁵ FTA Report No. 0030 Transportation Needs of Disadvantaged Populations

⁶ <http://www.vtpi.org/compstr.pdf>

⁷ Gibbs K, Slater SJ, Nicholson N, Barker DC, and Chaloupka FJ. *Income Disparities in Street Features that Encourage Walking – A BTG Research Brief*. Chicago, IL: Bridging the Gap Program, Health Policy Center, Institute for Health Research and Policy, University of Illinois at Chicago, 2012. http://www.bridgingthegapresearch.org/_asset/02fpi3/btg_street_walkability_FINAL_03-09-12.pdf

This disparity has major safety implications. Low-income census tracts have more than double the fatality rate (10.4 per 100,000) from traffic collisions as high income areas (5 per 100,000).⁸ Likewise, areas where more than 30% of the population live in poverty rate above 30% experience 12.6 traffic deaths per 100,000, compared with to 3.8 deaths per 100,000 in areas with less than 5% poverty. While low-income residential areas often have more access to transit, often only small portion of jobs are accessible by transit in a region. The Brookings Institution's Metropolitan Policy Program, which studied the largest urban areas in the United States, estimates that the average/median job shows that is accessible to 27 percent of its metropolitan workers by transit in 90 minutes or less. Results range from 64 percent of the population in Salt Lake City to 6 percent of the population in Palm Bay, Florida. Job accessibility by transit is being reduced by increased suburbanization of employment.⁹ In communities where transportation options are limited, employment may be difficult to maintain or secure.

The Equality of Opportunity Project, a Harvard/UC-Berkeley collaboration, has shown that location can factor greatly in economic mobility. In particular, upward mobility is higher in cities with less sprawl, as measured by commute times to work.¹⁰

Researchers have long explored approaches to reduce isolation from employment centers, education, and essential services, including housing reforms, economic development in low-income residential areas, and improved transportation connectivity. A recent study identified transportation connectivity as one of the most promising avenues to improve the lives of both low-income and middle-class families alike.¹¹

The Importance of Measurement

There is an old adage that “what gets measured, gets done” and this can certainly be applied to the evaluating the performance of the transportation sector. Connectivity is an important component to assess how well the transportation system is functioning and serving the people using it. This is an especially important gap to fill as we transition to a performance-driven transportation planning process.

MAP-21 introduced performance measures into the transportation system, requiring State and local transportation authorities to set standards for continuous improvement in the safety, maintenance, and operations of transportation facilities. In line with this approach, the Administration included funding for a \$70 million Connectivity Pilot Study in the GROW AMERICA Act, the results of which could eventually be used to inform a possible national connectivity in transportation measure. Such a national measure would allow investment in the areas and projects that are doing the most to promote economic mobility by improving access to jobs, education, and essential services through transportation infrastructure.

⁸ Maciag, Mike. “Pedestrians Dying at Disproportionate Rates in America’s Poorer Neighborhoods.” *Governing*. August 2014. <http://www.governing.com/topics/public-justice-safety/gov-pedestrian-deaths-analysis.html>

⁹ Tomer, Adie. “Where the Jobs Are: Employer Access to Labor by Transit.” *Brookings Institution Metropolitan Policy Program*. July 11, 2012. <http://www.brookings.edu/research/papers/2012/07/11-transit-jobs-tomer>

¹⁰ Leonhardt, David. “In Climbing Income Ladder, Location Matters.” *The New York Times*. July 22nd, 2013.

http://www.nytimes.com/2013/07/22/business/in-climbing-income-ladder-location-matters.html?pagewanted=all&_r=1&_r=1&_r=1

¹¹ Li, Huiping, Harrison Campbell, Steven Fernandez. Residential Segregation, Spatial Mismatch and Economic Growth across US Metropolitan Areas. *Urban Stud* October 2013 vol. 50 no. 13 2642-2660

In addition to advocating for a national study of connectivity, US DOT is already working with interested states and cities looking to improve connectivity for their residents. The Department is leveraging its programs and tools to share the connectivity measures currently in use and conduct a national conversation about improving connectivity.

Literature Review

Connectivity Measures in Practice by Local Governments

A number of Metropolitan Planning Organizations are employing measures and processes to address connectivity in their programs. In a survey developed by FTA and FHWA for member of the Association of Metropolitan Planning Organizations (AMPO) and the National Association of Regional Councils (NARC), 72% of the 108 respondents stated that their organization identifies gaps in the transportation system that limit access to essential services. 47% said they identify strategies for addressing these gaps, and 44% identify gaps in transportation systems for populations that are traditionally underserved.

Methods for defining transportation gaps for populations traditionally underserved vary as well, including overlay of Census and Department of Labor data, transit passenger surveys, inclusion of senior housing facilities in gap analysis, and use of HUD housing and poverty data. Additional strategies that MPOs use include GIS tools to identify distances of proposed projects from disadvantaged populations, usage maps of sidewalks, and analysis of bus routes to gauge needed improvements for disabled users and economically disadvantaged neighborhoods.

In the FHWA/FTA survey on measuring connectivity, MPOs identified a number of metrics that would be useful to establish baselines for connectivity in transportation systems including demographic data including age, race, English proficiency, and disability status; GIS data showing the location of essential services; economic data for households such as income and poverty level; transportation data including number of cars per household, proximity and frequency of transit service, travel destinations and times, as well as an accounting of barriers to travel between residences and essential services. Survey respondents also indicated that they would take development plans into consideration when calculating distance to essential services. Funding to collect this data and technical assistance to interpret data, including webinars and best practices, were identified as paths forward by surveyed MPOs. Other suggestions for improved data collection include adding questions of access to essential services to U.S. Census forms, issue Federal guidance for collecting data on connectivity, and Federal research on data collection and comparison to like regions.

From this survey and other research (CITE) it is clear that connectivity measures are under development or currently in use in a variety of ways across the country. The following case studies demonstrate the approach communities and local governments are taking to systemically find and address connectivity issues in their region. The case studies are divided into activities during the planning process (i.e. LRTP or Local Plan):

Table 1: Profile of Connectivity Measures

Location	Year	What	Goal	Measure	Data Elements	Data Sources
Atlanta	2011		Equity		Demographic	

					s, Education, Housing, Transportation	
Colorado Springs	2012	L RTP	Connectivity	% transit ridership increase over 5-year average, total # revenue service miles transit	NMT, public transit	
Denver	2012	HUD Grant	Accessibility	# of transit corridors, # of transit stations, walkability	Education, Health, Housing, NMT, public transit	RTD (transit routes and stops, existing and future (BRT, light rail, and bus, bike routes (DRCOG)
Kansas City	2010	L RTP	Accessibility	# of obligated TIP projects with bike/ped elements, % of total federal funds in EJ tracts	Environment, NMT, public transit	NTD-Annual Transit Profiles, TIP Program annual list of obligated projects (MARC)
Los Angeles	2013		Equity	15 minute frequency or less of existing and current light rail and bus rapid transit lines	NMT, public transit	Census LEHD 2010, Metro bus and light rail routes (LACMTA), bike facilities
Livingston County	2013	Local Plan	Connectivity			
Seattle	2011	HUD Grant	Opportunity	Proximity to transit, walkability	Education, Health, Housing, NMT, public transit	ACS 2005-2009 5-year estimates, bus stop locations (PSRC)
D.C.	2014	L RTP	Mobility	# of future transportation	Demographics, NMT, public	2010 U.S. Census Data,

				n options in a given place	transit	transit routes (WMATA), bike facilities
--	--	--	--	----------------------------	---------	---

Washington, District of Columbia (LRTP)

District Department of Transportation (DDOT) is the governmental agency responsible for the development and maintenance of transportation infrastructure within the nation’s capital. In 2014 DDOT released *MoveDC*¹², the city’s LRTP to address future development, jobs, and population along with transportation infrastructure that will support the increasing demand within Washington, D.C. *MoveDC* envisions a developed multimodal transportation network that connects all users. To improve the available number of transportation options in the city, the plan incorporates a Mobility Index¹³ to identify neighborhood accessibility and connectivity. Available transportation options measured by the index include:

- Protected bicycle facilities (trails, sidepaths, cycle tracks) with a 2-minute ride
- Bicycle facilities (bike lane) within a 2-minute ride
- Metrorail station within a 7 minute walk
- High-capacity transit station (including streetcar) within a 7.5 minute walk

To examine the current state of accessibility and connectivity within the District, DDOT overlaid 2010 U.S. Census data on top of the Mobility Index to identify mobility prone areas. The data displays that many neighborhoods except downtown are not well served by multimodal transportation options. According to the 2010 U.S. Census, 100% of District’s population has sidewalk access¹⁴, ≈ 40% has designated bike access, ≈ 15% has protected bike access, and ≈ 20% has Metrorail access. The Mobility Index demonstrates with the recommended transportation improvements identified in the plan, many neighborhoods will benefit from more transportation options along major travel corridors. By 2040, the plan states that 100% of the Districts’ population will have sidewalk access, ≈ 95% will have designated bike access, ≈ 80% will have protected bike access, ≈ 55% will have high-capacity transit access, and ≈ 25% will have Metrorail access by 2040. The Mobility Index will play a vital role in achieving the increase of access within the city’s transportation network and is a useful connectivity tool that could be replicated to advance connectivity in other metropolitan areas.

Colorado Springs, Colorado (LRTP)

The Pikes Peak Area Council of Governments (PPACG) is the regional MPO for Colorado Springs metropolitan area. In 2012, the MPO Board for PPACG adopted the *Moving Forward Update 2035 LRTP*¹⁵. Unlike previous plans, the plan incorporates performance-based decision-making. *Update 2035* identified 17 goals, with each goal assigned at least one performance measure and SMART (specific, measurable, agreed-upon, realistic, and time-bound) objectives. The objectives contain performance targets broken by time period and the performance measures provide data that is available and measurable to assess if the goal is met at the designated performance target.¹⁶

¹² District Department of Transportation (DDOT). *MoveDC LRTP*, http://www.wemovedc.org/resources/Final/Part%201_Strategic_Multimodal_Plan/Strategic_Multimodal_Plan.pdf

¹³ The Mobility Index is defined by the number of future transportation options available in a given place (pg. 88)

¹⁴ This designates that a sidewalk is available on at least one side of the street.

¹⁵ Pikes Peak Area Council of Governments (PPACG). *Moving Forward Update 2035 LRTP*, http://www.ppacg.org/files/TRANSP/LRTP-Jan2012/LRTP_complete.pdf

¹⁶ PPACG designated performance targets by three different time periods, 2015, 2025, and 2035

The incorporation of goals and SMART objectives in the plan led to the establishment of evaluation criteria. With input from the local community, the evaluation criteria were created, in order to assess all projects under consideration and evaluate projects relative to each goal. One evaluation criterion was established per goal for a total of 17 evaluation criteria. In order to identify the importance of each criterion, PPACG set up a weighting system for stakeholders and the public to rank each criterion. Out of 17 criteria, system connectivity¹⁷ was ranked as the second most important after maintaining or improving current transportation system infrastructure.

The following performance measures will help identify whether PPACG is making strides to improve system connectivity throughout the region:

- Decrease the number of locations with connectivity and accessibility barriers such as gaps in system connectivity
- Increased number of system connectivity components, such as transit transfer locations, park-and-ride lots, trailheads, new roadway connections, etc.

PPACG does not provide the methodology for how the two performance measures will be measured. Still, PPACG is working to provide more concrete performance measures by developing their regional transportation plan for 2040. *Moving Forward 2040* is very similar in format to the *Update 2035* plan and incorporates performance measures. In 2014, the PPACG Board of Directors approved to reduce the number of goals from 17 to 13 and modify some of the performance measures. System connectivity remained as one of the top evaluation criteria, but the performance measures changed to include:

- Non-motorized System Connectivity and Accessibility Index¹⁸ This is difficult because I still have not come across a document that displays the methodology or data used to measure this
- Percent Transit Ridership Increase Annually Over 5-Year Average
- Total number of Revenue Service miles for transit passenger service

The increase in the amount of measures demonstrates a committed approach by PPACG to reduce the number of connectivity issues. By incorporating performance measures that relate to connectivity, PPACG can better quantify the number of connections within the region's transportation network.

Kansas City, Missouri (LRTP)

Mid-America Regional Council (MARC) is the council of governments and MPO that services the bistate Kansas City region. In June 2010, the MPO board approved *Transportation Outlook 2040*, the city's LRTP to handle more than \$18 billion in economic investment in the region's transportation network. In order to track the performance of the transportation system, MARC incorporated performance measures in the LRTP.

Within the LRTP there are set of goals and factors that outline the performance measures. The nine goals range from accessibility to safety and security. The accessibility goal provides three factors that aim to improve connectivity. The factors with the designated performance measures (included in parentheses) are listed below:

- Level of Transit Service (total revenue service hours, average transit boardings per revenue service hours)

¹⁷ System connectivity is the evaluation criteria; Improve system connectivity within and between modes and accessibility for everyone is the goal,

http://www.fhwa.dot.gov/planning/performance_based_planning/mlrtp_guidebook/fhwahep14046.pdf

¹⁸ PPACG has not provided data what data is incorporated in this tool

- Bicycle/Pedestrian Accessibility (number of obligated TIP projects with bicycle/pedestrian elements)
- Environmental Justice (percent of total federal funds invested in environmental justice tracts)¹⁹

Through one year of reporting, data shows that there are increases in the measures. The number of obligated TIP projects with bicycle and pedestrian elements increased by 77 percent. In addition, the percentage of total federal funds invested in EJ tracts increased 7.6 percent.

Livingston County, New York (Local Plan)

Livingston County, a county with a population of 65,000, is part of the Rochester Metropolitan Statistical Area located east southeast of Buffalo, New York. In 2013, Livingston County developed and released the Livingston County Transportation Connectivity Plan to address growing needs presented by multiple members of the community, including no reliable forms of transportation and the demand for transportation among all age groups. After a 2008 county-wide community needs assessment, Livingston County recorded that almost 50% of low-income residents surveyed indicated that they did not have a reliable form of transportation to access needed services or employment.²⁰

To address the needs, six goals were established within the plan to make Livingston County more multimodal and improve the region’s quality of life. Under each of the six goals, several strategies were established to support the completion of the goal. Furthermore, evaluation criteria were “developed to highlight the differences between the strategies evaluate the strategies for the county—wide plan”.²¹

Connectivity was listed as one of several criteria:

- Connectivity within & outside Livingston County: Considers the improvement or establishment of a new connection(s) between destinations within/outside the County.

In order to provide better connectivity, Livingston County conducted a needs assessment to identify the needs and gaps within the County. Livingston County completed a transit need using two different methodologies. The second method, the mobility gap method which is incorporated into the Transit Cooperative Research Program 49 document, looks at the difference between the number of trips taken by zero vehicle households and the number of trips taken by one vehicle households relying on data from the National Household Travel Survey (NHTS) for nine census regions. Livingston County is incorporated into the Middle Atlantic region, a region with 3.1 trips per day for zero vehicle households and 5.9 trips per day for one vehicle households. This leads to a mobility gap of 2.7 trips per day. According to ACS data, there are 1,270 household with zero vehicles in Livingston County. Using the mobility gap of 2.7, individuals in these household would make 3,429 more trips per day if they had the mobility of one vehicle households. Based on a 250-working-day-year, this is an additional 857,250 trips if all of these trips were taken on the local public transportation system.

Livingston County notes that in order to provide service to each user would require additional revenue and service that the county cannot provide. Instead, the county conducted a transit demand study using three methods. The three methods provide results to where the demand for improved connectivity lies within the transportation network.

¹⁹ Mid-America Regional Council (MARC). Transportation Outlook 2040 Executive Summary. 2012. <http://www.to2040.org/assets/plan/ExecutiveSummary.pdf>

²⁰ Livingston County, NY. Livingston County Transportation Connectivity Plan. Web. <http://www.co.livingston.state.ny.us/Index.aspx?NID=110>

²¹ Livingston County, NY. Connect Livingston Linking Our Communities, Final Report: Transportation Connectivity Plan, <http://www.co.livingston.state.ny.us/DocumentCenter/View/996>, pg. 2

Madison, Wisconsin (LRTP)

The Madison Area Transportation Planning Board is the regional MPO for the greater Madison area which includes the city of Madison and the surrounding cities, counties, and towns that are incorporated in the Madison Urbanized Area. For the 2040 regional transportation plan, the TPB is aiming to incorporate performance indicators to understand how well planning goals and investment decisions are connected. The proposed indicators for the Madison Area include both “outcome” metrics that measure the effects of system investments and decisions (e.g., travel time, mode of transportation, roadway and bridge conditions, # of crashes) as well “output” metrics that measure the level of activity of a program or supply of a service or facility (e.g., transit revenue hours of service, miles of multi-use paths). Outcome measures are preferable because they provide an indication of the effectiveness of a given level of activity or supply of facilities. However, good outcome measures are not available in some cases, particularly system-wide measures, due to the lack of readily available data or other reasons. The selected indicators are a starting point, and it is expected that the measures will change and grow in the future as the necessary data or resources become available for more innovative tools such as those measuring accessibility or travel time reliability.

Texarkana, Texas (LRTP)

Texarkana MPO is the regional planning organization for the Texarkana region which services cities and counties in both Arkansas and Texas. In 2014, the MPO adopted the *2015-2040 Metropolitan Transportation Plan LRTP* to layout the vision for future development in the Texarkana region. Similar to the LRTPs developed in Colorado Springs and Kansas City, the plan incorporates performance measures to track the condition and performance of the regional transportation system and to further understand how well planning goals and investments decisions are connected. Alongside the performance measures set forth by the United States Department of Transportation according to MAP-21, the MPO held several meetings with local community members in order to get their thoughts on what other performance measures would best benefit the people of Texarkana. From the discussions the MPO highlighted criteria pertaining to accessibility and connectivity, specifically performance measures involving non-motorized transportation. These performance measures include:

- Percent of parks accessible by bikes and pedestrians
- Percent of schools accessible by bikes or pedestrians
- Linear feet of connectivity gaps filled²²

The performance measures listed above are potential items up for discussion for future LRTPs. If added to the plans, they are concrete examples on how to measure connectivity and fill gaps within the transportation network so all users can arrive and depart to destination with ease. Going forward, the MPO will incorporate further performance measures like the ones mentioned above not required by federal and state mandate. The examples noted above verify that communities are already providing tools through the federal planning process to combat connectivity issues and ensure all individuals are not limited to opportunities in the future. The incorporation of performance measures provides even greater examination of connectivity issues in the transportation network because data is available and measurable for up-to-date analysis. The next section reveals the role equity plays in providing connectivity and what measures are currently available.

The examples in Washington, D.C. Colorado Springs, and Kansas City verify that communities are already providing tools through the federal planning process to combat connectivity issues and ensure all

²² Texarkana 2015-2040 Metropolitan Transportation Plan,
<http://www.texarkanamp.org/documents/Tuts/TUTS%202040%20Plan.pdf>

individuals are not limited to opportunities in the future. The incorporation of performance measures provides even greater examination of connectivity issues in the transportation network because data is available and measurable for up-to-date analysis. The next section reveals the role equity plays in providing connectivity and what measures are currently available.

Measuring the Equity of Regional Connectivity

As communities continue to increase the number of connections within a designated area, there are also strong messages being stated to make sure the effects are distributed equally. In the case of public transportation, researchers have been focused in the area of transit network design that has not generally incorporated issues pertaining to equity and access. Instead most public transportation network design and research focuses on minimizing operational costs and maximizing service coverage (Ferguson et al., 2011).²³ With this focus in mind, connectivity between populations and destinations is reduced, particularly among low income and minority populations who rely on public transportation more than other population groups.

There is shift throughout the country among MPO's, local governments, transit agencies, and public and private stakeholders to promote equity assessments throughout regional transportation networks to identify whether the network is providing access and mobility to all users. The following case studies examine how incorporated disadvantaged populations are in respect to various indicators, including transportation. The data sources for the case studies include the American Community Survey, U.S. Census Bureau, local public transit routes and stops, and bicycle facilities.

Puget Sound Regional Council (HUD SCI)

The Puget Sound Regional Council (PSRC) is the MPO for the four counties that incorporate the Seattle/Puget Sound Region. In 2010, PSRC was the recipient of a \$5 million HUD SCI grant to improve coordination between housing and transportation planning with infrastructure and land use within the region. As a result of the grant PSRC partnered with local public, private, and non-profit stakeholders to establish the Growing Transit Communities (GTC) partnership. GTC is a collaboration of regional stakeholders committed to creating an equity network that fosters the socioeconomic development of underserved populations around multimodal transportation networks.

GTC is comprised into four works programs, one of which is the creation of a Regional Equity Network. In 2012, GTC aligned with the Kirwan Institute²⁴ to develop the report "Equity, Opportunity, and Sustainability in the Central Puget Sound Region Geography of Opportunity in the Central Puget Sound Region".²⁵ In order to map the geography of opportunity in the region, the report highlights various definitions related to opportunity including:

- Social Equity- All people, regardless of where they live, have access to the resources and opportunities that improve their quality of life and let them reach their full potential.
- Opportunity- A situation or condition that places individuals in a position to be more likely to succeed and excel

²³ Ferguson et al. *Incorporating Equity into the Transit Frequency-Setting Problem*. 2011.

²⁴ Kirwan Institute is an Ohio State university-wide research institute that highlights racial and ethnic disparities in communities.

²⁵ Puget Sound Regional Council (PSRC). *Equity, Opportunity, and Sustainability in the Central Puget Sound Region Geography of Opportunity in the Central Puget Sound Region*, <http://www.psrc.org/assets/7831/EquOppSusReport2.pdf>

The report displays a comprehensive view of opportunity in the four county region in relation to a range of societal and economic indicators. The indicators of opportunity identified in the report are highlighted under the following categories (item in parentheses identifies the indicator):

- Education (WASL scores reading/math, teacher qualification, student poverty and graduation rates)
- Economic Health (living wage jobs with 15 minutes auto/30 minutes transit, job growth trends, unemployment rate)
- Housing and Neighborhood Quality (housing vacancy, foreclosure, and high cost loan rates, housing stock condition, crime index)
- Mobility and Transportation (cost per commute, **access to transit**, average transit fare cost, **walkability**)
- Health and Environment (distance to park, toxic waste per square foot, access to healthy food)

In conclusion, the report generated a Comprehensive Opportunity Map of the five categories. There were also maps that were generated by each category. The Mobility and Transportation Opportunity Map is a useful tool displays useful data, in particular the access to transit indicator which identifies the percentage of the total area that is within ¼ mile of an Express Bus stop. The walkability element is also useful for connectivity as it identifies the percentage of all commuters who walk to work; signifying a higher area of walkers within a community might indicate better connectivity in the transportation network at that designated area. A similar report was generated by the MPO for the Denver metropolitan area.

Denver Regional Council of Governments (HUD SCI)

The Denver Regional Council of Governments (DRCOG) is the MPO for the Denver metropolitan area. In 2012, DRCOG was the recipient of a \$4.5 million HUD SCI grant to increase cooperation among local stakeholders in the regional planning process. The grant helped establish the Mile High Connect (MHC) partnership, a joint venture between regional stakeholders aiming to improve access between education, housing, and jobs, by means of public transportation.²⁶ Two MHC members, Reconnecting America and the Piton Foundation²⁷, generated the report “Denver Regional Equity Atlas Mapping Access to Opportunity at a Regional Scale”.

The major component of the report is the Equity Atlas, an online interactive tool that examines the geography of the current and future transportation system in relation to major activity centers.²⁸ The Equity Atlas is divided among five topics:

- Population and Demographic Characteristics of the Region
- Access to Affordable, Quality Housing Options
- Access to Jobs and Economic Development Opportunities
- Access to Educational Opportunities
- Access to Health Care, Healthy Foods, and Recreational Facilities

The focus of access in the report is around transit corridors and transit stations. The maps provide ¼, ½, and 1 mile buffers around FasTrack stations, the regional light rail system in Denver, which could be the

²⁶ Mile High Connects (MHC). <http://www.milehighconnects.org/main.html>

²⁷ Reconnecting America and the Piton Foundation are both members of the MHC partnership.

²⁸ Denver Regional Equity Atlas, <http://www.reconnectingamerica.org/assets/Uploads/equityatlas-complete-final-web.pdf>

basis for access for the maps. Because of this, the report has varied definitions for access. The report states access to healthy food for residents of subsidized housing show places with low food access, defined as census tracts that are more than one mile from a grocery store. However, access to quality preschools for children under 5 shows preschools within a half-mile radius of existing and planned FasTracks stations. Altogether, the Equity Atlas yields similar results as those found in the Opportunity Maps from PSRC. The only difference between both tools is that the Equity Atlas does not create area ranking by opportunity level. The Equity Atlas also contains a few different indicators but has the same categories.

The examples above exhibit connectivity measures from MPOs that are occurring outside of the federal planning process. MPOs are finding alternative ways to address connectivity issues through the creation of local committees or regional partnerships. Furthermore, the Opportunity Mapping and Regional Equity Atlas are forward-thinking tools that can be replicated by most communities to address connectivity issues. The development of such tools reveals how regional collaboration among stakeholders can improve the needs of all individuals by enhancing accessibility and connectivity within the transportation network in order to provide ladders of opportunity.

Los Angeles Equity Atlas

In 2013, Reconnecting America, a nonprofit that works to promote transportation and economic development throughout the nation, and the California Community Foundation, a Los Angeles philanthropic organization, released the Los Angeles Equity Atlas. The Equity Atlas is an online interactive tool that ensures that Los Angeles County's new future is inclusive and offers housing, education, economic, and health opportunities for low- and moderate-income residents and workers.²⁹

The main component of the Equity Atlas is "frequent transit," which examines existing and current light rail and bus rapid transit corridors, as well as rapid buses that operate every fifteen minutes or better. The Equity Atlas overlays the transit network on different measures, such as education, food, and jobs and the workforce. This provides a current image of performance within Los Angeles County and identifies areas with gaps and assets in individual communities, along corridors, or in station areas along the frequent transit lines. The atlas also examines the existing pedestrian and bicycle facilities and analyzes the current network along with the room for growth in order to build a multimodal transportation network.

The Equity Atlas focuses around four themes, the first of which is increasing mobility, access, and connectivity. It is noted that transit connectivity within the County is good with 47% of jobs proximate to frequent transit.³⁰ This is useful figure due because LACMTA carries the second highest amount of passengers per day in the country after New York MTA. A big contributor to the amount of transit passengers per day is due to non-motorized transportation. A 2011 Metro Onboard Survey revealed that 85% of current transit riders walk, bike, or use wheelchairs to get to transit. This reveals that many individuals take non-motorized modes of transportation to get to public transportation. Furthermore, many of these individuals have an opportunity to get to jobs within the County.

²⁹ Reconnecting America and California Community Foundation. "Los Angeles Equity Atlas". 2013.

³⁰ Reconnecting America and California Community Foundation. "Los Angeles Equity Atlas". 2013.

Atlanta Equitable Target Areas

The Social Equity Advisory Committee³¹ is a committee formed by the ARC, the regional planning organization for greater Atlanta, to provide guidance to ARC on matters that relate to low-income, minority, and underrepresented populations. In 2011, through collaboration with the committee, ARC developed the Equitable Target Areas (ETA) Index to identify potential environmental justice (EJ) locations in the Atlanta region. Using data from the American Community Survey (ACS) 5-year estimates (2005-2009), ETAs were developed based on five parameters:

- Age
- Education
- Median Housing Value
- Poverty
- Race

The ETA Index is helping to identify future connectivity issues in the Atlanta region. The parameters from the Index were used to measure the impacts of Plan 2040³² investments and programs in ETA communities. By combining Plan 2040 with the ETA Index, in particular the GIS³³ tools incorporated from the Index, researchers can identify transportation and socioeconomic relationships with the goal of addressing future connectivity issues.

Academic and Theoretical Examples

The academic community has also been developing connectivity measures that can be of use to state and local governments; their findings can also inform this effort.

Accessibility Observatory (2014)

Under the leadership of Dr. David Levinson at Department of Civil Engineering, University of Minnesota, the Accessibility Observatory builds on earlier work conducted at the University of Minnesota, including the Access to Destinations study(2004-2012) using the methods and tools developed by this project as a starting point for an integrated, multi-modal accessibility evaluation system that can be applied nationwide. The Observatory also builds on the Access Across America Report (2013) that provides aggregate metro-level auto accessibility metrics, expanding on this work by calculating and analyzing accessibility at the Census block level, and by including both auto and transit in a unified evaluation framework. To generate the rankings for Accessibility Observatory, Levinson created a weighted average of accessibility, giving a higher weight to closer jobs. Jobs reachable within 10 minutes are weighted most heavily, and then jobs are given decreasing weight as travel time increases up to 60 minutes. The researchers are launching a Pooled Research Fund to continue their work. <http://access.umn.edu/>

Missed Opportunity: Transit and Jobs in Metropolitan America (2011),

The Metropolitan Infrastructure Initiative, Brookings Institution assembled database of schedule and geospatial data for all transit systems in the nation's largest 100 metropolitan areas, combined with neighborhood-level information on income and employment.

www.brookings.edu/about/programs/metro/~/_link.aspx?id=7e50ef8e7a324b01a1d136a1243854a0&lang=en&z=z

³¹ Atlanta Regional Commission (ARC). ARC Social Equity Advisory Committee, <http://www.atlantaregional.com/transportation/community-engagement/social-equity>

³² Plan 2040 is a combination of Atlanta's regional transportation plan and regional plan incorporated into one document

³³ Geographic Information Systems (GIS)

LEED Neighborhood- Development (LEED-ND)

The U.S. Green Building Council developed [in 2007] a pilot LEED_ND system, informed by the Charter for the New Urbanism, to recognize greener neighborhood plans and designs. The goal was to go beyond green buildings alone to certify the "greenness" of overall plans. Such plans reduce land consumption and automobile dependence as well as promote pedestrian activity, good air quality, and other livability and sustainability goals. Relevant to the community in the present study, LEED-ND 2007 pilot criteria award points for pedestrian-friendly features such as siting 50% of homes within 0.5 miles of school, lining streets with four-foot wide sidewalks, and bringing buildings close to the sidewalk . www.biomedcentral.com/content/pdf/1479-5868-8-139.pdf

Exploring Access to Low-income Jobs in the Urban Core (2013), by Hart, N. and N.E. Lownes, published by Transportation Research Board Washington. Explain the various levels of households with low incomes and high rates of car ownership (LIHCO households) in the urban core by investigating their accessibility to low-income job locations. It is measured by using two transit accessibility metrics that are geared toward low-income populations. The first is based on the number of low-income jobs accessible by transit from the residential location. The second metric is based on late-night frequency at the residential location. www.worldtransitresearch.info/research/5032/

Walk Score (2014). While not an academic endeavor, Google veterans founded the company Walkscore to use Google's data and complex algorithms to create interactive databases that can be used across the United States to build "travel sheds" showing population, jobs, and amenities within a certain distance of a location, by mode, for more than 300 cities; Matt Lerner of Walk Score has helped developed companion tools such as Transit Score. (Nb: The Walk Score advisory board includes urban planning, environmental and technical experts from institutions such as the Sightline Institute and the Brookings Institution). www.walkscore.com

Measuring Sprawl (2014), by Reid Ewing, Professor of City and Metropolitan Planning, University of Utah and Shima Hamidi, Graduate Research Assistant, University of Utah. The Measuring Sprawl report builds on earlier work: the Measuring Sprawl and Its Impact study released by Smart Growth America and conducted by Reid Ewing; Rolf Pendall, Cornell University and Don Chen, Smart Growth America. Measuring Sprawl updates that research and analyzes development patterns in 221 metropolitan areas and 994 counties in the United States as of 2010, looking to see which communities are more compact and connected³⁴ and which are more sprawling; and includes a list of the most compact and most sprawling metro areas in the country. This report also examines how scores gathered from a Sprawl Index³⁵ relate to life in that community. The researchers found that several quality of life factors improve as Sprawl Index scores rise. Individuals in compact, connected metro areas have greater economic mobility. Individuals in these areas spend less on the combined cost of housing and transportation, and have greater options for the type of transportation to take. Finally, this report includes specific examples of how communities are building to be more connected and walkable, and how policymakers at all levels of government can support their efforts. <http://www.smartgrowthamerica.org/measuring-sprawl>

³⁴ More compact and connected areas are associated with scores higher than 100 from the Sprawl Index (described in further detail below). Scores lower than 100 are more sprawling.

³⁵ The Sprawl Index is based four factors, development density, land use mix, activity centering, and street accessibility, where the factors are combined in equal weight and controlled for population to calculate each area's Sprawl Index score.

Transportation Needs of Disadvantaged Populations: Where When and How (2013), by Fang Zhao and Thomas Gustafson, of Florida International University. The purpose of the project was to use a combination of data sources, including the Census Transportation Planning Package (CTPP) and employment and housing data, to develop a methodology to assess the transit markets in terms of residential and job locations for low-income households; determine the temporal distribution of transit demand, especially for off-peak periods; analyze the housing availability to low-income families in relation to job locations; and evaluate existing transit services for improvements and potential development opportunities. http://www.fta.dot.gov/documents/FTA0030_Research_Report_Summary.pdf

Sustainable Community Indicator Catalog (2014), released by the University of Pennsylvania’s Penn Institute for Urban Research; the HUD Office for International and Philanthropic Innovation and the Partnership for Sustainable Communities. The Catalog helps communities identify indicators that can measure progress toward their sustainability objectives. The indicators in this catalog focus on the relationships among land use, housing, transportation, human health, and the environment. The researchers evaluated over 100 community indicator initiatives across the United States and identified over 1,000 examples of indicators being used to measure community progress related to the Partnership for Sustainable Community’s Livability Principles. Some of the indicators noted in the SCIC include arterial roads with bike lanes, bike parking per capita, and the percentage of population that lives within ¼ miles of bike lane/trail. <https://acquia-dev.sustainablecommunities.gov/indicators>

Analysis

Common themes from these case studies, research papers, and theoretical models emerge to show a good operational definition of connectivity.

One common element in all these is considering disadvantaged populations and special needs sub-populations. Transportation projects must help to erase barriers to economic inclusion. To this end, plans should be evaluated by their potential to : (1) increase job access via public transportation; (2) decrease commute times for low-income people, communities of color, and people with disabilities; (3) increase proximity to high-frequency transit for neighborhoods with high proportions of people without cars; (4) decrease transportation costs for low-income people; (5) increase access to affordable housing in the vicinity of a new transit project (preservation of existing or creation of new affordable housing); (6) decrease transportation costs for low-income people; and (7) decrease pedestrian injuries and fatalities, particularly for people of color and people in rural communities.

The following table examines the indicator (Data Elements) used for measuring connectivity:

Table 2: Common Accessibility/Connectivity Data Measures by Location

City	Demographics	Education	EJ	Food	Health	Housing	Transportation
Atlanta	X	X				X	
Colorado Springs							X
Denver	X	X		X	X	X	X

Kansas City			X	X		X	X
Los Angeles	X	X		X	X	X	X
Livingston County							X
Seattle	X	X		X	X	X	X
D.C.							X

Next Steps and Application

Taken together this points to an ideal workable measure that includes:

- 1) Places people need to be connected to
- 2) Frequency of connections
- 3) Timing of connections
- 4) Weighting for connections
- 5) Safety/environmental impacts of connections
- 6) Measures of travel times by mode/time of day
- 7) Population characteristics that affect connection needs (school age children, elderly)
- 8) Destination characteristics that affect connection needs (workplaces, grocery stores, pharmacies, parking)

And that could be used for a variety of planning purposes like:

- 1) Transit planning;
- 2) Environmental Justice planning
- 3) General urban & transportation planning
- 4) Measuring effectiveness of transportation services
- 5) Emergency response and evacuation planning
- 6) Siting of schools and other public services

But there are operational and practical considerations that make uses for connectivity measures challenging. For example,

Conclusion

US DOT is proposing a few Potential Next Steps to advance the state of practice around connectivity.

Summit

Convene a summit of stakeholders to share institutional and analytical best practices

Research

Identify the state of the practice to better understand the institutional and analytical challenges transportation agencies face as they work to improve access to opportunity;

Pilots

Develop and share analytical techniques so that State DOT's, MPOs, providers of public transportation and local transportation agencies can more easily measure the degree to which disadvantaged populations have access to jobs, essential services, and other opportunities and identify policies and projects to increase access.